Free-fall drop test rig to replicate head impacts in ice hockey

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Introduction

Ice hockey has one of the highest concussion rates in sports, and ~90% of reported concussions occur during collisions with other players [1], although only falls (onto the ice or against the surrounding boards) are represented in current certification standards (e.g. [2]). Collisions between players, typically cause lower accelerations and higher impact durations than falls [3]. Helmet tests in the literature use a variety of specialist laboratory equipment to replicate the various collisions and falls [4], while certification tests are not representative of collisions between players. A simplified test protocol based on ice-hockey head impacts that commonly cause concussion, could facilitate helmet tests that are more representative of ice hockey head impacts. This could improve ice hockey helmet research and development.

Methods

A 50th percentile male Hybrid III headform, equipped with a DTS Slice Nano sensor system (Diversified Technical Systems, Inc., 3 linear accelerometers and 3 angular rate sensors (both 100 kHz sampling frequency)), was fitted with five different ice hockey helmets. Linear acceleration and angular velocity were measured during impacts onto a flat anvil, and 45^{o} inclined plane, using a free-fall drop test; (Filter: CFC 1000 (linear) & CFC 180 (angular)). During flat anvil impacts, five different surfaces (MEP Pad (1-inch height, CadexInc) and layered EVA (EVAZOTE-50, algeos.com) foam sheets bonded with double sided tape to 24, 48, 72, and 96 mm overall thickness) were applied. During impacts onto the 45° inclined surface, three layered EVA foam thicknesses (24, 48, and 72 mm) were applied. Video footage (Phantom, Miro R311, 2,000 fps, 500 µs exposure 1024 x 768 pi, 0.5 mm/pi) was recorded to explain impact events and measure impact velocity. This was synchronised manually to acceleration vs. time data by matching the start and end of impacts. Similar to certification tests [2], drops were carried out from a height of 1 m, resulting in an impact energy of 51.3 – 53.8 J. Three centric impact sites (front, side, rear) were impacted 3 times for each flat impact surface, while additional non-centric impact sites (front boss and rear boss) were used for each oblique impact surface [2]. All tests were repeated with the unhelmeted headform.

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Results

Acceleration vs. time data (Fig. 1 A) show a single peak, characteristic of collision type head impacts [5]. The highest linear and angular accelerations and shortest impact durations were produced during impacts onto rigid surfaces (Fig. 1 B) (angular data not shown here for brevity). With increasing impact surface compliance, peak linear and angular accelerations decreased, whilst impact durations increased (Fig. 1B).

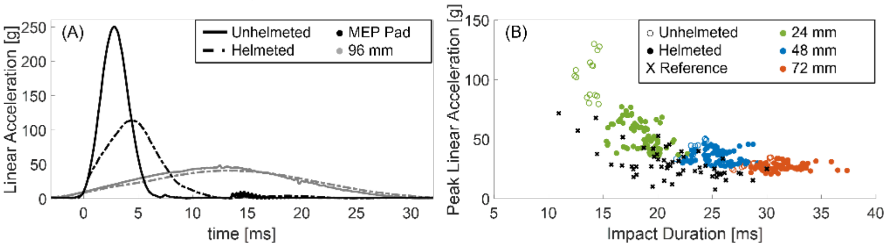

Fig. 1: (A) Linear acceleration vs. time for unhelmeted and helmeted Front site impacts onto the flat MEP Pad and 96 mm EVA foam; (B) Peak linear acceleration vs. impact duration for all oblique impacts, and reference data from [4].

Discussion

A broad range of headform kinematic responses during impact were obtained, affected by impact surface compliance and orientation. The relative difference in peak accelerations between helmeted and unhelmeted impacts decreased with increasing impact surface compliance, as expected [3]. The linear, and angular acceleration vs. time data (angular not included here for brevity), during drops onto 24 and 48 mm, were similar in shape [5] and magnitude [4] to the characteristic kinematic responses of ice hockey head impacts recreated in a laboratory. These free-fall drop test conditions reproduce common concussive impacts caused by collision between ice hockey players, based on current knowledge of ice hockey head impacts. Further work developing biofidelic headforms and monitoring concussive head impacts in ice hockey is still required.

References

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